Working Group 5 Summary

NuFact 2022 – Snowbird, Utah & U. Utah

Richard Ruiz on behalf of WG5

Institute of Nuclear Physics – Polish Academy of Science (IFJ PAN)

August 6 2022

Thank you LOC for your great support!

Thank you to fellow organizers, administrators, participants, chairs, speakers[1], and particularly Team WG5

Koun Choi (IBS) and Ian Shoemaker (Virginia Tech.)

[1] Thank you for uploading your talks before sessions began! ☺☺☺

Working Group 5: New physics beyond PMNS

NuFact 2022 is the twentythird in the series of yearly international workshops which started in 1999. The main goal of the workshop is to review the progress of current and future facilities able to improve on measurements of the properties of neutral and charged lepton flavor violation, as well as searches for new phenomena beyond the capabilities of presently planned experiments.

The main goal of the workshop is to review the progress of current and future facilities able to improve on measurements of the properties of neutral and charged lepton flavor violation, as well as searches for new phenomena beyond the capabilities of presently planned experiments. The workshop is both interdisciplinary and interregional in that experimenters, theorists, and accelerator physicists from all over the world share expertise with the common goal of reviewing the results of currently operating experiments and designing the next generation of experiments. To allow for worldwide participation we plan to broadcast plenary sessions and make selected parallel sessions available. Plenary sessions will be mostly held in the mornings in Utah, which translates into convenient times for international participants from the Americans and Europe/Africa regions. NuFact will include some dedicated hybrid events with opportunities for remote participants to give presentations and to discuss with the in-person participants.

Before and during the conference we will also have several mini-workshops and panel discussions. We will have the following events: (1) Multi-messenger Tomography of Earth Workshop (MMTE 2022)[July 30-31, 2022], (2) ESSnuSB+ Workshop, (3) Early career scientist career development workshop, and a panel discussion on the Snowmass exercise.

We are planning a fully in-person event. Plenary and selected parallel sessions will be streamed for world-wide participation. NuFact will include some dedicated virtual events with opportunities for remote participants to give presentations.

The **NuFact 2022** workshop program consists of plenary sessions, parallel sessions with **seven Working Groups** covering the following topics:

1. Neutrino Oscillation Physics (Working Group 1),
2. Neutrino Scattering Physics (Working Group 2),
3. Accelerator Physics (Working Group 3),
4. ~~Muon Physics (Working Group 4), and~~
5. Neutrinos Beyond PMNS (Working Group 5)
6. ~~Detectors (Working Group 6)~~
7. Inclusion, Diversity, Equity, Education & Outreach (Working Group 7)

Day 1 (Monday)

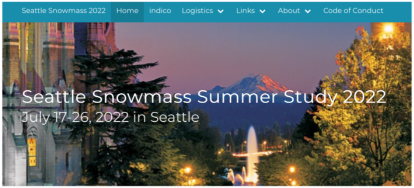
Snowmass Status (T. Han)

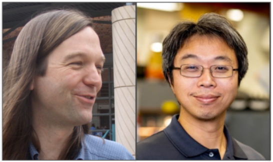
Snowmass 2021 finally happened! (in July 2022)

Community Summer Study (CSS): Snowmass 2021

July 17 – 26, 2022 @ UW – Seattle

http://seattlesnowmass2021.net





Gordon Watts
email
Co-Chair of Local Organizing Committee, Co-Chair of Program Committee

Shih-Chieh Hsu
email
Co-Chair of Local Organizing Committee, Co-Chair of Program Committee

Participants

Number of in-person participants: 743

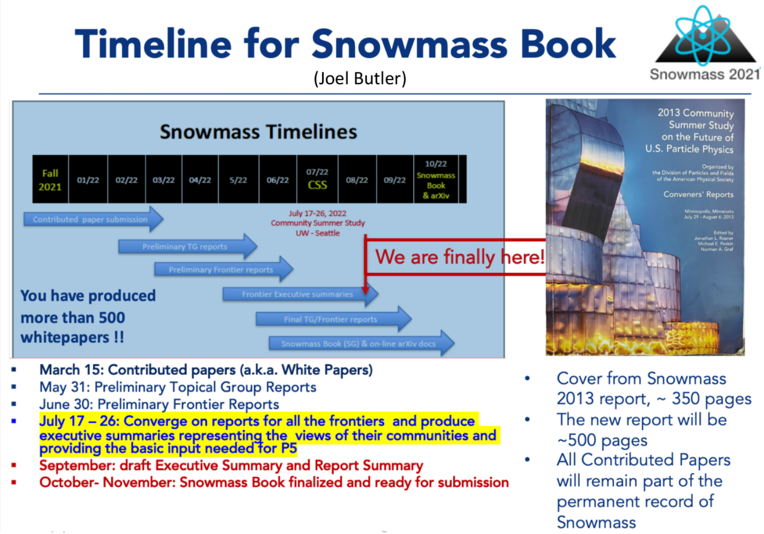
Number of virtual participants: 654

Local Organizing Committee/Volunteer/Press: 58

Total number of participants: 1397

Snowmass Status (T. Han)

Too much for a summary talk but progress toward completion!



Take away: ν physics is new physics

The science drivers for NF

(Patrick Huber)

- What are the neutrino masses?
- Are neutrinos their own antiparticles?
- How are the masses ordered?
- What is the origin of neutrino mass and flavor?
- Do neutrinos and antineutrinos oscillate differently?
- Discovering new particles and interactions
- Neutrinos as messengers

Significant growth in activity since last Snowmass

Why are neutrino masses still Beyond the Standard Model Physics?

We do not know how to write neutrino masses:

- Are ν data described by left-handed Majorana masses?

$$\Delta\mathcal{L} = \frac{1}{2} m_L \overline{\nu_L^c} \nu_L \quad \text{(maybe!)}$$

- Are ν data described by right-handed Majorana masses?

$$\Delta\mathcal{L} = \frac{1}{2} m_R \overline{\nu_R^c} \nu_R \quad \text{(not by itself!)}$$

- Are ν data described by Dirac masses?

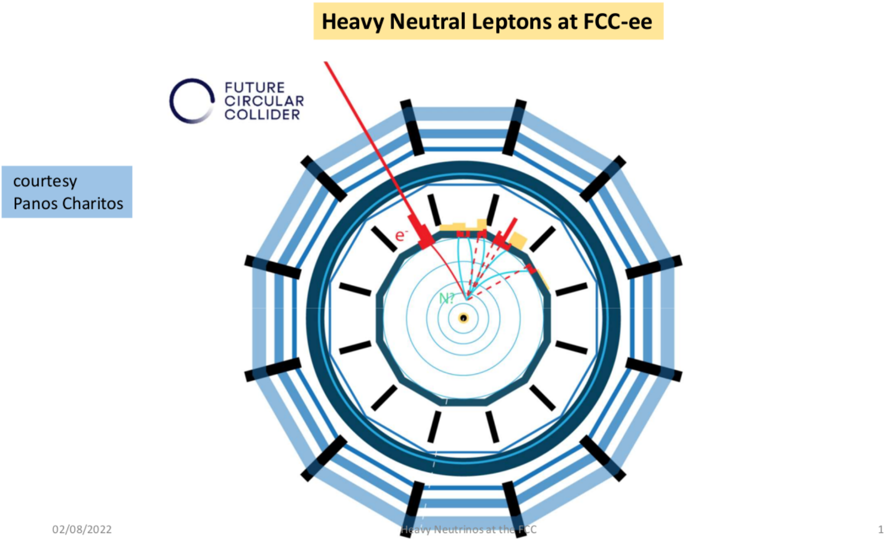
$$\Delta\mathcal{L} = m_D \overline{\nu_L} \nu_R + \text{H.c.} \quad \text{(maybe, but I hope not!)}$$

Experimentally establishing $1/2$ is probably worth a prize... 

Day 2 (Tuesday)

Heavy neutrinos at the FCC-ee (A. Blondel)

Testing neutrino mass models at the Future Circular Collider (e^+e^- mode)



Heavy neutrinos at the FCC-ee (A. Blondel)

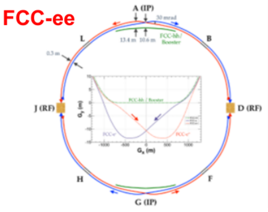
Future Circular Collider: the future of CERN and the field?

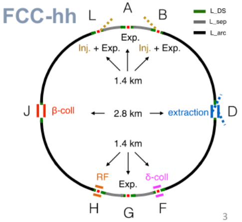
Synergy: The FCC integrated program at CERN

Comprehensive cost-effective program inspired by successful LEP – LHC success story

- **Stage 1: FCC-ee (Z, W, H, tt) as first generation Higgs EW and top factory at highest luminosities.**
- **Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options.**
- **Maximizes physics output with strong complementarity**
- Integrating an ambitious high-field magnet R&D program
- Common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure.
- Start construction early 2030's, start data taking shortly after HL-LHC completion
- **FCC-INT project plan is fully integrated with HL-LHC exploitation ➔ seamless continuation of HEP**
- **Feasibility study approved and funded at CERN (100MCHF/5yrs) + magnet R&D (120 MCHF/6yrs)**

*** **GLOBAL COLLABORATION** ***

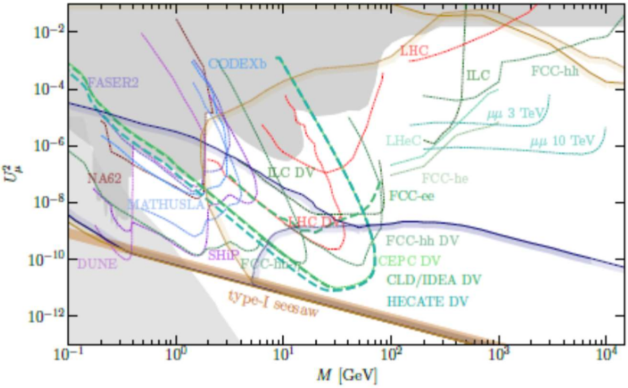




01.08.2022 Alain Blondel FCC-ee Physics 3

Heavy neutrinos at the FCC-ee (A. Blondel)

Promising outlook for directly testing (minimal) Type I Seesaw



4 event lines for LLP signature (Exclusion if you do the search and find nothing!) 5 10^{12} events

Revisiting group-theoretic properties of $(3+n)$-mixing matrices

PMNS and the number of additional neutrino flavors

Janusz Gluza

University of Silesia, Katowice, Poland

NuFact

2 August 2022, Snowbird, SLC, Utah, USA

Supported by NATIONAL SCIENCE CENTRE POLAND

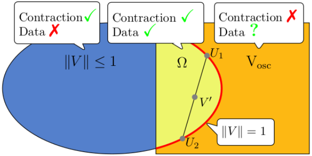
PMNS and the number of add'l neutrino flavors (J. Gluza)

"Matrix theory can help to find relations between eigenvectors, eigenvalues of light and heavy mass spectrum $\Longrightarrow$ mass [flavor] matrix modeling."

Mixing space

(I) U_{int} and the Physical Region of Mixing (Convex Hull of U_{PMNS})

$$\Omega := \mathrm{conv}(U_{\mathrm{PMNS}}) = \{\sum_{i=1}^{m} \alpha_i U_i \mid U_i \in U(3), \alpha_1, ..., \alpha_m \geq 0, \sum_{i=1}^{m} \alpha_i = 1,$$
$$\theta_{12}, \theta_{13}, \theta_{23} \text{ and } \delta \text{ given by experimental values}\}$$



We proved that the Carathéodory's number is **m** $\leq$ **4**, instead of 10(19) for CP ($\cancel{CP}$) cases, e.g., for the 3+1 scenario, two U_{PMNS} matrices are enough to span the corresponding subset of Ω region.

Fig. from PRD2018, $V_{osc} \equiv U_{int}$

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μBooNE test of MiniBooNE's low-energy excess

Search for an Anomalous Excess of Electron Neutrino Interactions in MicroBooNE and New Constraints on eV-Scale Sterile Neutrinos

Xiangpan Ji (BNL)
On behalf of the MicroBooNE collaboration

NuFact 2022
The 23rd International Workshop on Neutrinos from Accelerators
Salt Lake City, Utah, United States
July 31st – Aug. 6th, 2022

μBooNE: Search for an Anomalous Excess of ν_e (X. Ji)

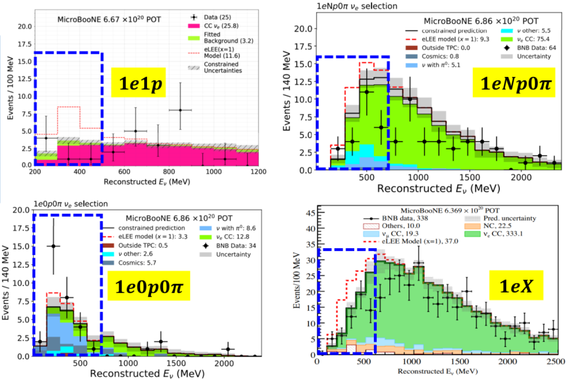
μBooNE: "Disfavor pure ν_e excess as a sole source of MiniBooNE excess at 3σ level"

Theorist's commentary: only half of μBooNE's full data set released! ☺

Unblinded Results

- Unblinded in summer 2021
- No observation of ν_e candidate excess in low energy region, except for the low-ν_e-purity ($1e0p0\pi$) channel

Phys. Rev. D105, 112003 (2022)
Phys. Rev. D105, 112004 (2022)
Phys. Rev. D105, 112005 (2022)
Phys. Rev. Lett. 128, 241801 (2022)



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Day 3 (Wednesday)

Overview of cLFV in the muon sector (J. Kriewald)

Exploring relationship between ν physics and μ physics

Overview of cLFV in the muon sector (J. Kriewald)

ν mass models intimately related to charged lepton flavor violation

Peculiar cLFV patterns

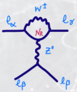
cLFV signals – correlations matter

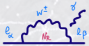
Synergy of cLFV observables **very important:** probe different operators/topologies

$\mathrm{BR}(\mu \to e\gamma), \mathrm{BR}(\mu \to eee), \mathrm{CR}(\mu - e, \mathrm{N})$ **correlated** by **common topologies:**

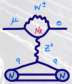
γ **dipoles & anapoles**, Z **penguins**, **tree-level contributions,... ⇒4-fermion operators**

Model-dependent: certain topologies **dominate**, **tree-level cont. might be present**





Model	$\mu \to eee$	$\mu N \to eN$	$\frac{\mathrm{BR}(\mu\to eee)}{\mathrm{BR}(\mu\to e\gamma)}$	$\frac{\mathrm{CR}(\mu N\to eN)}{\mathrm{BR}(\mu\to e\gamma)}$
MSSM	Loop	Loop	$\approx 6\times10^{-3}$	$10^{-3} - 10^{-2}$
Type-I seesaw	Loop*	Loop*	$3\times10^{-3} - 0.3$	0.1–10
Type-II seesaw	Tree	Loop	$(0.1-3)\times10^{3}$	$\mathcal{O}(10^{-2})$
Type-III seesaw	Tree	Tree	$\approx 10^{3}$	$\mathcal{O}(10^{3})$
LFV Higgs	Loop†	Loop*†	$\approx 10^{-2}$	$\mathcal{O}(0.1)$
Composite Higgs	Loop*	Loop*	$0.05 - 0.5$	$2 - 20$



Calibbi et al. [1709.00294]

⇒ study correlations/ratios of cLFV observables, **might find peculiar cLFV patterns**

⇒ **provide complementary information to direct searches**

In EFT: **RGE** leads to operator mixing, **need to consider as many** observables as possible

to constrain $\mathscr{L}^{\text{eff}} = \mathscr{L}^{\text{SM}} + \frac{\mathscr{C}^5\,\mathscr{O}^5}{\Lambda_{\text{LNV}}}(m_\nu) + \frac{\mathscr{C}^6\,\mathscr{O}^6}{\Lambda^2_{\text{cLFV}}}(\ell_i \leftrightarrow \ell_j) + \ldots + \frac{\mathscr{C}^9\,\mathscr{O}^9}{\Lambda^5_{\text{LNV}}}(0\nu2\beta) + \ldots$

See S. Davidson NuFact 2021

Jonathan Kriewald LPC August 3rd 2022 21

Day 4 (Thursday)

Charged-meson-induced new physics in beam-focused ν experiments (D. Kim)

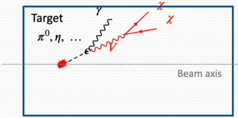
Charged-meson-induced new physics in beam-focused ν experiments (D. Kim)

Scalar portal, neutrino portal, vector portal, now meson portal!

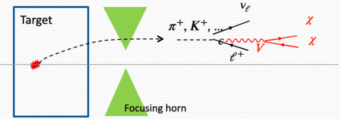
Charged Meson vs. Neutral Meson

In the example of vector-portal dark matter,

Production via neutral meson



Production via charged meson



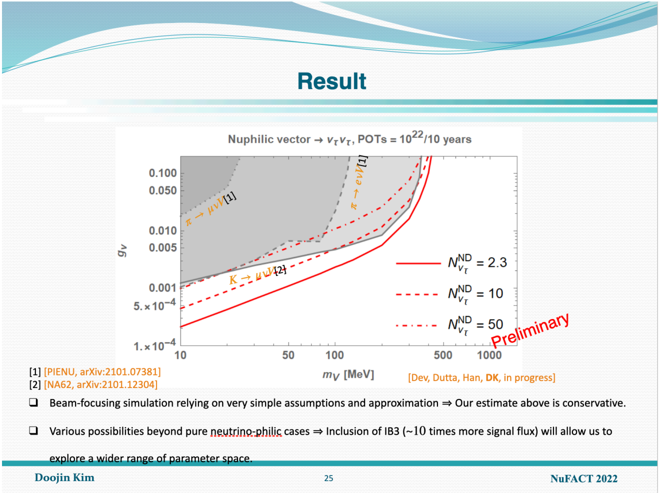
$$N^{\chi}_{\pi^0-\text{ind}} = \cancel{N}_{\pi^0} \bullet \text{BR}(\pi^0 \to V \to \chi) \bullet f^{\chi}_{\pi^0-\text{ind}} \ll N^{\chi}_{\pi^\pm-\text{ind}} = \cancel{N}_{\pi^\pm} \bullet \text{BR}(\pi^\pm \to V \to \chi) \bullet f^{\chi}_{\pi^\pm-\text{ind}}$$

- Comparable production rate: $\pi^0 : \pi^+ : \pi^- : \eta : K^+ : K^- \approx 1:1:1:0.1:0.1:0.1 \Rightarrow N_{\pi^0} \approx N_{\pi^\pm}$
- No BR enhancement vs. Large BR enhancement $\Rightarrow \text{BR}(\pi^0 \to V \to \chi) \ll \text{BR}(\pi^\pm \to V \to \chi)$
- Unfocused π^0, η vs. Focused $\pi^\pm$, $K^\pm$
- Wider spreading π^0, η-induced flux vs. Forward-directed $\pi^\pm$, $K^\pm$-induced flux $\Rightarrow f^{\chi}_{\pi^0-\text{ind}} < f^{\chi}_{\pi^\pm-\text{ind}}$

Production via **charged meson** can be more efficient than production via **neutral meson**!

Doojin Kim 14 NuFACT 2022

Charged-meson-induced new physics in beam-focused ν experiments (D. Kim)



Modular symmetries and the flavor problem (D. Meloni)

Building models for flavor with guidance from group theory

THE UNIVERSITY OF UTAH®

Modular symmetries and the flavor problem

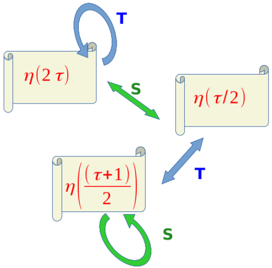
Davide Meloni
Dipartimento di Matematica e Fisica, Roma Tre

Modular symmetries and the flavor problem (D. Meloni)

Not easy but possible to predict patterns in Yukawa couplings (Y)

A case study: $\Gamma_2 \sim S_3$

Constructing the Modular Forms



the system is closed under modular transformation

candidate modular form

$$Y(\alpha,\beta,\gamma)=\frac{d}{d\tau}\left[\alpha\ \log\eta(\tau/2)+\beta\ \log\eta((\tau+1)/2)+\gamma\ \log\eta(2\tau)\right]$$

$$\alpha+\beta+\gamma=0$$

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(the title says it all!)

Phenomenology of Dark Sectors at the Short Baseline Neutrino Experiments

Joshua Berger
Colorado State University

PRD 104, 075026: B. Batell, JB, L. Darmé, C. Frugiuele
Fortcoming: B. Batell, JB, J. Dyer, A. Ismail
Snowmass Report 2207.06898

August 4, 2022

NuFact 2022 - WG5

Dark Pheno. at the Short Baseline ν Expts (J. Berger)

Theorist's (personal) commentary: experimental and theoretical progress mediated by continuous development of simulation tools (rich physics in their own right) (remember next time you review a grant! ☺☺☺)

The State of Simulation

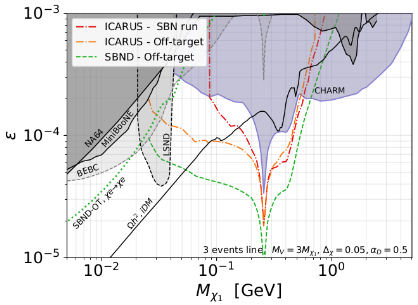
	Production					Dark $\to$ Standard					
Process	Brem.	Direct	Prompt	LL	Flux	Decay	e	N El.	N Inel.	Det.	Reco.
MadDump		✓	✓		✓		✓		✓		
BdNMC	✓	✓	✓		✓	✓	✓	✓	✓		
GENIE							✓	✓	✓		
Geant4			✓	✓	✓	✓				✓	
ACHILLES						✓	✓	✓	✓		
FORESEE	✓	✓	✓	✓	✓	✓	✓	✓			

Building the BSM / new physics portfolio for ICARUS and SBND

Possible "Off-Target" Run

MiniBooNE steered BNB off target and into absorber

Can reduce distance DM needs to travel *and* bkg



Joshua Berger 15

Coherent ν scattering and the quenching factor measurement (J. Liao)

Exploring opportunities with coherent ν scattering

Coherent neutrino scattering and quenching factor measurement

Jiajun Liao

Sun Yat-sen University

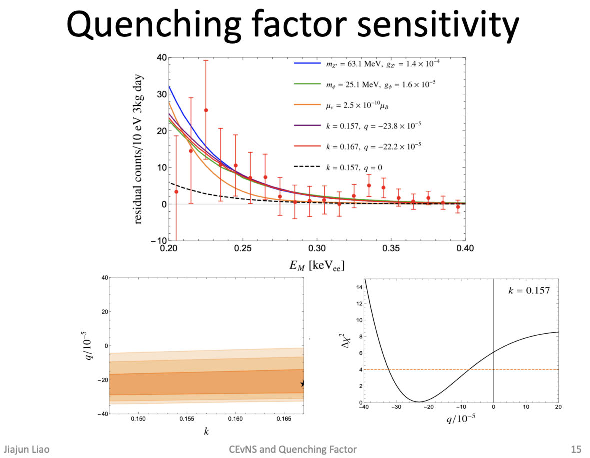
In collaboration w/ Hongkai Liu and Danny Marfatia

arXiv: 2104.01811, Phys. Rev. D 104, 015005 (2021)
arXiv: 2202.10622, accepted as a Letter in PRD

NuFact 2022: 23rd International Workshop on Neutrinos from Accelerators
Cliff Lodge@Snowbird, 8/4/2022

Coherent ν scattering and the quenching factor measurement (J. Liao)

Exploring opportunities with coherent ν scattering



Day 5 (Friday)

Connection between ν mass models and μ expts (J. Heeck)

Snowmass summary (the title says it all!)

Connection between neutrino mass models and muon experiments

Julian Heeck

NuFact 2022, Utah, USA

08/05/2022

UNIVERSITY of VIRGINIA

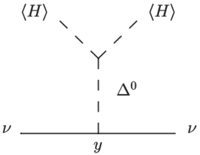
Connection between ν mass models and μ expts (J. Heeck)

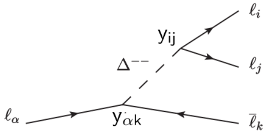
ν mass models are deeply connected to LFV

Scalar-triplet (type-II) seesaw

[Konetschny & Kummer '77; Magg & Wetterich, '80; Schechter & Valle '80; Cheng & Li, '80; Mohapatra & Senjanovic, '81]

$$\mathrm{L} = \mathrm{L}_{\mathrm{SM}} + |\mathrm{D}_\alpha \Delta|^2 - (\mathrm{y}_{\alpha\beta} \overline{\mathrm{L}}^{\mathrm{c}}_\alpha \Delta \mathrm{L}_\beta + \mu \mathrm{H} \Delta \mathrm{H} + \mathrm{h.c.})$$





$$\Rightarrow \quad (\mathrm{M}_\nu)_{\alpha\beta} \simeq \mathrm{y}_{\alpha\beta} \frac{2\mu \mathrm{v}^2}{\mathrm{M}_\Delta^2} \quad \& \quad \mathrm{BR}(\ell_\alpha \to \ell_\mathrm{i} \ell_\mathrm{j} \bar{\ell}_\mathrm{k}) \propto |(\mathrm{M}_\nu)_{\alpha\mathrm{k}}|^2 |(\mathrm{M}_\nu)_{\mathrm{ij}}|^2.$$

[Pich, Santamaria, Bernabeu, '84; Abada++, 0707.4058]

$\boxed{\text{Prediction of LFV } \textit{ratios} \text{ via } \mathrm{M}_\nu!}$

CDF's W-mass first hint for this triplet with O(100 GeV) mass? [Heeck, 2204.10274]

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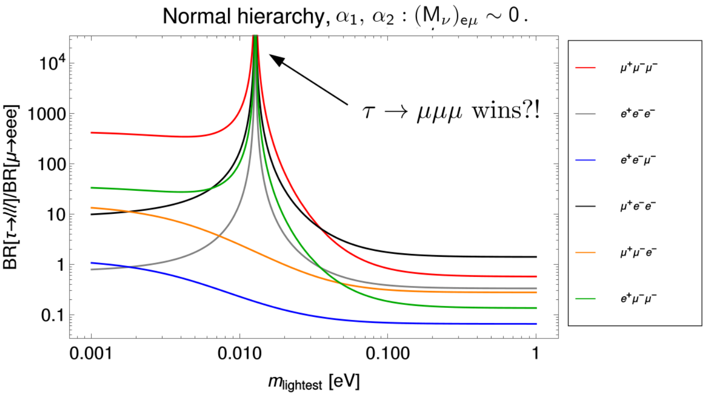
Connection between ν mass models and μ expts (J. Heeck)

Some (not all) ν mass models make firm predictions for LFV



$$\Rightarrow \quad (M_\nu)_{\alpha\beta} \simeq y_{\alpha\beta} \frac{2\mu v^2}{M_\Delta^2} \quad \& \quad BR(\ell_\alpha \to \ell_i \ell_j \bar{\ell}_k) \propto |(M_\nu)_{\alpha k}|^2 |(M_\nu)_{ij}|^2.$$

NuFact '22 Julian Heeck - Neutrino mass and muons 20

PROBING BSM MODELS AT FUTURE HIGH-PRECISION LONG BASELINE EXPTS (A. Giarnetti)

Building the BSM / new physics portfolio for DUNE and HyperK

PROBING BSM MODELS AT FUTURE HIGH-PRECISION LONG BASELINE EXPERIMENTS

ALESSIO GIARNETTI

ROMA TRE UNIVERSITÀ DEGLI STUDI

NuFact2022, SLC, 5th August 2022

PROBING BSM MODELS AT FUTURE HIGH-PRECISION LONG BASELINE EXPTS (A. Giarnetti)

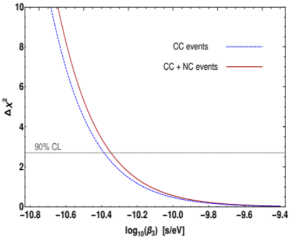
Building the BSM / new physics portfolio for DUNE and HyperK

INVISIBLE DECAY MODEL

Since one neutrino mass state decays during his lifetime, the total number of neutrinos at the Far Detector, is not the same as the number of neutrinos produced at the source! Indeed

$$\sum_{\alpha}^{e,\mu,\tau} P_{\mu\alpha} = 1 + (e^{-\frac{L}{\beta_3 E}} - 1)\cos^2\theta_{13}\sin^2\theta_{23} \neq 1$$

- Being the number of Neutral Current events proportional to the total number of neutrinos (the NC interactions are flavor independent), we found out that this new channel would improve the DUNE sensitivity to the decay parameter!



New constraint 5.1×10−11 s/eV

Evolution of Lepton Number for Neutrinos (N. Benoit)

Revisiting field-theoretic definition of lepton number

Evolution of Lepton Number for Neutrinos

Nicholas J. Benoit (Hiroshima University, D3)

Collaboration with:
A. S. Adam (BRIN); Y. Kawamura (HU); Y. Matsuo (HU)
T. Morozumi (HU, CORE-U); Y. Shimizu (HU, CORE-U)

Based on:
A. S. Adam, **NJB**, Y. Kawamura, Y. Matsuo, T. Morozumi, Y. Shimizu, Y. Tokunaga and N. Toyota, PTEP 2021, (2021) [arXiv:2101.07751 [hep-ph]]
A. S. Adam, **NJB**, Y. Kawamura, Y. Matsuo, T. Morozumi, Y. Shimizu and N. Toyota, [arXiv:2106.02783 [hep-ph]]

NuFACT 2022, University of Utah, August 01-06 1/45

Evolution of Lepton Number for Neutrinos (N. Benoit)

Field-theoretic def. of lepton number for Dirac and Majorana ν

Framework for the lepton number operator

Majorana mass case

- the step-function separates our formulation into two regions $\mathcal{L}^M = \overline{\nu_{L\alpha}} i\gamma^\mu \partial_\mu \nu_{L\alpha} - \boxed{\theta(t)} \left(\frac{m_{\alpha\beta}}{2} \overline{(\nu_{L\alpha})^C}\, \nu_{L\beta} + \text{h.c} \right)$

Region 1 (t<0)	Region 2 (t>0)
• Massless neutrinos $\mathcal{L}^M = \overline{\nu_{L\alpha}} i\gamma^\mu \partial_\mu \nu_{L\alpha}$ • The lepton family number is definite – i.e. lepton numbers are conserved $L^M_\alpha = \int d^3x\, l^M_\alpha(\mathbf{x}) = \int d^3x : \overline{\nu_{\alpha L}}(\mathbf{x}) \gamma^0 \nu_{\alpha L}(\mathbf{x}) :$	• Massive neutrinos $\mathcal{L}^M = \overline{\nu_{L\alpha}} i\gamma^\mu \partial_\mu \nu_{L\alpha} - \left(\frac{m_{\alpha\beta}}{2} \overline{(\nu_{L\alpha})^C}\, \nu_{L\beta} + \text{h.c} \right)$ • The lepton family number is mixed and time dependent $L^M_\alpha(t) = \int d^3x\, l^M_\alpha(t, \mathbf{x}) = \int d^3x : \overline{\nu_{\alpha L}}(t, \mathbf{x}) \gamma^0 \nu_{\alpha L}(t, \mathbf{x}) :$ • Diagonalize mass matrix with the unitary PMNS matrix $\nu_{\alpha L} = U_{\alpha i} \nu_{iL}$ $m_i \delta_{ij} = (U^T)_{i\alpha} m_{\alpha\beta} U_{\beta j}$

Our goal is to connect these two regions

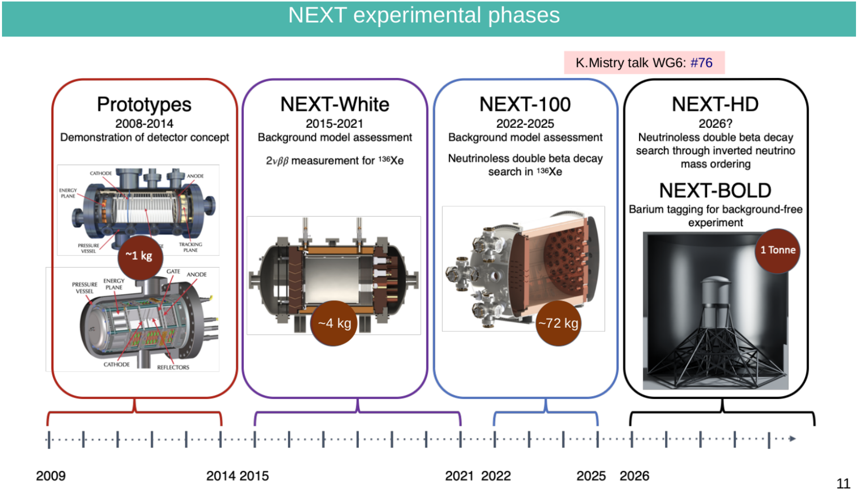
NuFACT 2022, University of Utah, August 01-06 7/45

Towards $0\nu\beta\beta$ decay in NEXT (G. Díaz)

Searches for $0\nu\beta\beta$

Towards $0\nu\beta\beta$ decay in NEXT (G. Díaz)

progress in the race to discover a factor of 1/2



Towards $0\nu\beta\beta$ decay in NEXT (G. Díaz)

prospects on the race to discover a factor of 1/2 

NEXT-100 sensitivity

preliminary

- Estimated background rate from radiogenic origin (radiopurity measurements + simulation) **< 3.6 counts/year**
- Estimated background rate from cosmogenic origin (flux + simulation) ~ **0.9** (prompt-γ, 90% eff μ-veto) + **0.3** (^{137}Xe) **counts/year**

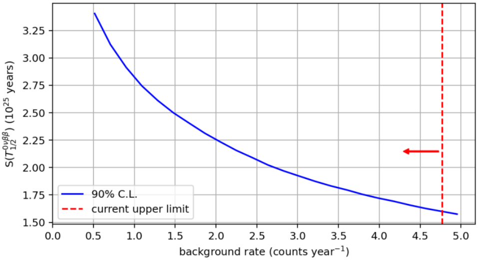
tentative NEXT-100 running time: **3 years**

^{136}Xe atoms: **72 kg @ 90%**

$$S(T_{1/2}^{0\nu\beta\beta}) = \log(2) \cdot \epsilon_s \cdot \frac{t \cdot N_0}{S(b)}$$

signal eff: **21 %**

background mean C.I.



$$S(T_{1/2}^{0\nu\beta\beta}) > 1.6 \times 10^{25} \text{ years}$$

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Tests of ν mass models at ATLAS (B. Wynne)

Direct searches for Seesaw particles

Tests of neutrino mass models at ATLAS

B. Wynne
On behalf of the ATLAS collaboration
University of Edinburgh

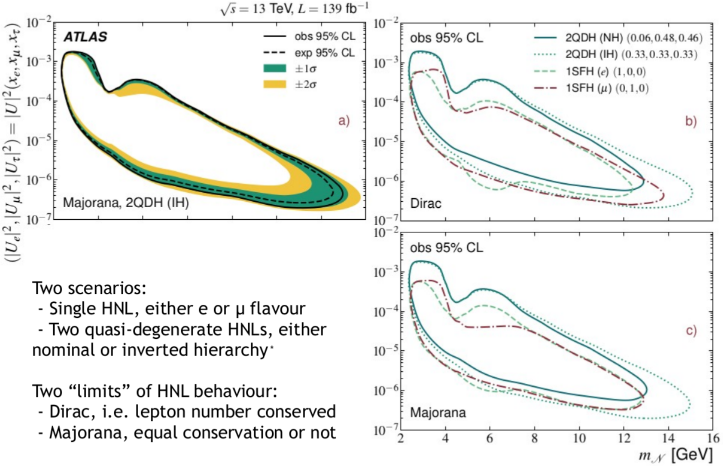
05/08/22

Tests of ν mass models at ATLAS (B. Wynne)

Direct searches for light, long-lived heavy neutrinos

Type 1 seesaw HNL search

2022



Two scenarios:
- Single HNL, either e or μ flavour
- Two quasi-degenerate HNLs, either nominal or inverted hierarchy*

Two "limits" of HNL behaviour:
- Dirac, i.e. lepton number conserved
- Majorana, equal conservation or not

*2QDH is the more realistic model, and this is the first direct search with this interpretation

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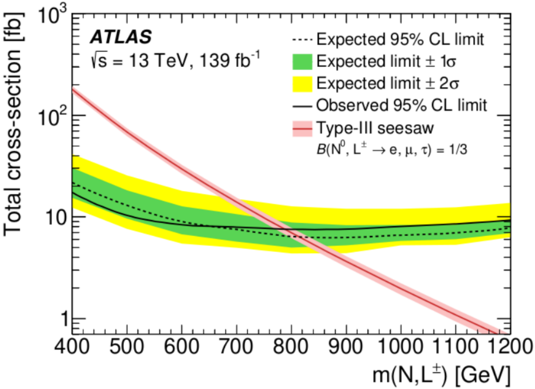
arxiv:2204.11988

Tests of ν mass models at ATLAS (B. Wynne)

Direct searches for heavy, vector-like leptons

Type 3 seesaw search (2 lepton)

Limits set as usual, excluding HNL masses (and those of the charged heavy leptons) below 790 GeV



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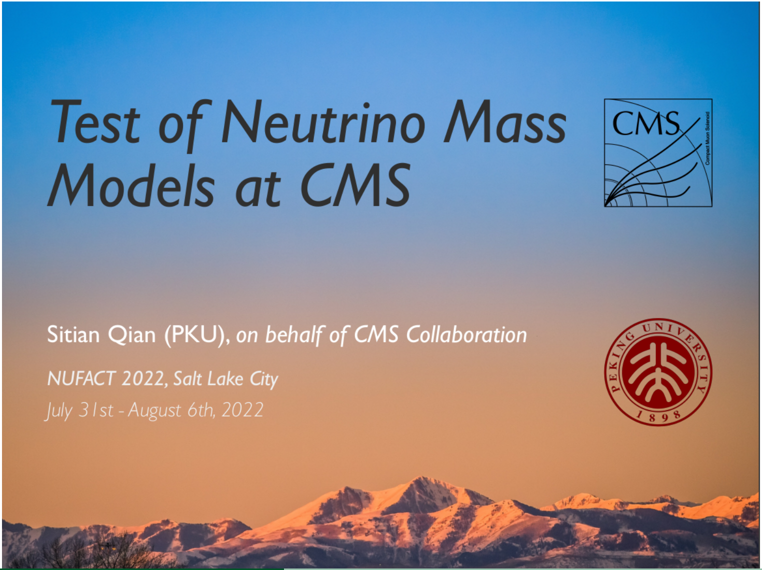
arxiv:2202.02039

Tests of ν mass models at CMS (S. Qian)

Direct searches for Seesaw particles

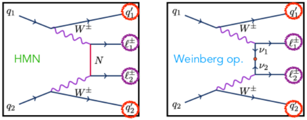


Tests of ν mass models at CMS (S. Qian)

searches for $0\nu\beta\beta$ at the LHC (race to the factor of 1/2)

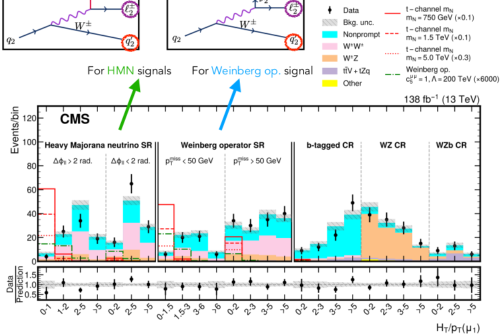
PROBING HEAVY MAJORANA NEUTRINOS & WEINBERG OP. VIA VBF

EXO-21-003
arXiv: 2206.08956

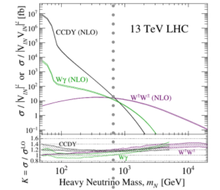


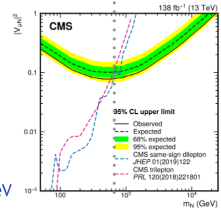
Jets: clustered by Anti-K_T with radius R=0.4 (AK4)

For HMN signals
For Weinberg op. signal



$qq \to W \to \ell N$
VBF t-channel





- **HMN**: m_N excluded up to ~ **23 TeV** & best limits since ~ **650 GeV**!
- **WO**: **obs.** (exp.) upper limit on effective mass $|m_{\mu\mu}|$: **10.8** (12.8) GeV

Test of Neutrino Mass Models at CMS, Sitian Qian (PKU) on behalf of CMS Collaboration, NUFACT 2022, July 31st - August 6th, 2022

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Tests of ν mass models at CMS (S. Qian)

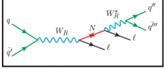
Many more new ideas to search for left-right symmetry and **lepton number violation** (race to the factor of 1/2)

LRSM Charged Current Search

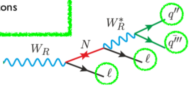
EXO-20-002
JHEP04(2022)047

- Charged current search: W_R and N_ℓ
  - Final state leptons are of the same flavor:
    - Search channels: both **dielectron** and **dimuon** considered
    - Signal topology: **Resolved** and **Boosted**

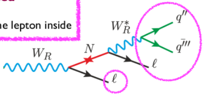
Charged Current



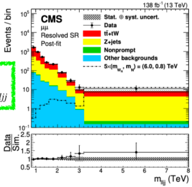
Resolved
- Two leptons
- Two jets



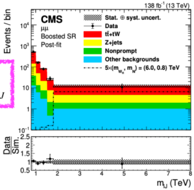
Boosted
- One lepton
- One fatjet with one lepton inside



Resolved:
Invariant mass m_{lljj}



Boosted:
Invariant mass m_{lJ}



Test of Neutrino Mass Models at CMS, Sitian Qian (PKU) on behalf of CMS Collaboration, NUFACT 2022, July 31st - August 6th, 2022

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that was a lot.... that was not everything either, but no more time

new physics (and WG5 ☺!) **is at the core of ν physics**

Thank you and see you all (I hope) at NuFact 2023!